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Review of Design, Construction and Repair of TCRA Armoring for West Berm of San Jacinto Waste Pits

FINAL REPORT--October 2013

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Preface

This technical review document, Review of Design, Construction and Repair of TCRA Armoring for West Berm of San Jacinto Waste Pits, was developed by the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC), Environmental Laboratory (EL), Vicksburg, MS. This document provides a technical review of the design, construction and repair documents for the Time Critical Removal Action for the West Berm of San Jacinto River Waste Pits Superfund Site. The document was prepared for the EPA Region 6, Dallas, TX, under a Superfund Work Authorization Form (WAF) for San Jacinto River Waste, TX, agreement No. DW96950490-011.

Dr. Paul R. Schroeder of the USACE Environmental Engineering Branch (EP-E), Environmental Processes and Engineering Division (EPED), EL, ERDC performed the review and wrote this report. The EPA Region 6 point of contact for this report is Federal On-Scene Coordinator (FOSC) Valmichael Leos. This study was conducted under the direct supervision of Mr. W. Andy Martin, Chief of EP E, and under the general supervision of Mr. Warren Lorentz, Chief of EPED, Dr. Beth Fleming, Director of EL, Dr. Jeffery P. Holland, Director of ERDC, and Col. Jeffrey R. Eckstein, EN, Commander of ERDC.

Executive Summary

This review examined the Time Critical Removal Action Alternatives Analysis (June 2010), Final Removal Action Work Plan (Feb 2011), Revised Final Removal Action Completion Report (May 2012), TCRA Cap Repair Plan (July 2012), Time Critical Removal Action Report on Reassessment of Design and Construction (April 2013), and miscellaneous construction submittals and weekly reports for the West Berm of San Jacinto River Waste Pits Superfund Site.

The armor design followed the armor layer design procedures of the EPA ARCS Guidance for In-Situ Subaqueous Capping of Contaminated Sediments (EPA 905-896-004) (Palermo et al. 1998). However, the design should have considered wave runup and overtopping as described in the USACE Coastal Engineering Manual (Part VI) EM 1110-2-1100 (1 June 2006) as was performed in the Reassessment of Design and Construction (April 2013). The procedures develop design specifications for armor size and material, filter material, armor gradation, thickness and slope. The Armor Cap B/C design was selected for the west berm. The design called for a geotextile to be placed on the natural foundation with minimum regrading following clearing and grubbing. Next, 12 inches of highly non-uniform recycled concrete was to be placed on the geotextiles, characteristic of a blended armor/filter layer. The design specified recycled concrete having a D_{50} of 6 inches and a D_{100} of 12 inches. The natural slope prior to clearing and grubbing ranged from 1V:10H to 1V:2H.

The armor size (D_{50} and D_{100}) was generally appropriate, but the material did not meet the uniformity required for slopes steeper than 1V:3H. Under high bottom shear stresses from high velocities (greater than 4.3 fps) or large breaking waves, loss of gravel and sand sized particles occurs at slopes steeper than 1V:3H. In addition, displacement of armor material (rolling down slope if not lodged in the cap) occurs as voids are formed by the losses. The thickness of the cap was suitable for the size of the armor material used; however, the thickness of the armor material should have been adjusted to augment the natural slope to a surface slope of 1V:3H or flatter. Alternatively, sandy fill could have been placed on the natural foundation to flatten the slope to 1V:3H prior to placement of the geotextile.

The construction specifications and testing for the Armor Cap B/C material were not adequate to ensure that the material had the design uniformity. A procedure should have been in place to verify the uniformity coefficient of the armor cap material. Ideally, a grizzly screen would have been used at the site to remove particles less than two inches in size from the Armor Cap B/C material.

The repair plan should address the west berm armor instability adequately by placing uniform Armor Cap C natural rock in the maintenance area if a maximum slope no greater than 1V:3H is achieved. The two largest areas of concern discovered in this review were the steep foundation slope following clearing and grubbing and the use of non-uniform recycled concrete. Both are addressed in the repair plan, but I would urge limiting the slopes to no greater than 1V:3H in areas of potential wave runup or high bottom shear stress.

Review of Design and Construction of TCRA Armoring for West Berm of San Jacinto Waste Pits

1 Background

This review of the design and construction of TCRA armoring for west berm of San Jacinto Waste Pits, TX is being conducted to address the performance of the armoring during a recent flood/storm event estimated to be a 10-year return event. Following the event, considerable movement or loss of armor material was discovered as evident in Figures 1, 2, 3 and 4.

Figure 1. West berm.

Figure 2. Exposed geotextile near crown.

The armor design for the west berm of the San Jacinto Waste Pits followed the armor layer design procedures of the EPA ARCS Guidance for In-Situ Subaqueous Capping of Contaminated Sediments (EPA 905-896-004) (Palermo et al. 1998). The procedures include considerations for stone sizing and gradation, thickness, filtering, and apron length. Additional design considerations should include bearing capacity, slope stability of the foundation and the capping material, permeability, wave runup and overtopping as described in the USACE Coastal Engineering Manual (Part VI) EM 1110-2-1100 (1 June 2006).

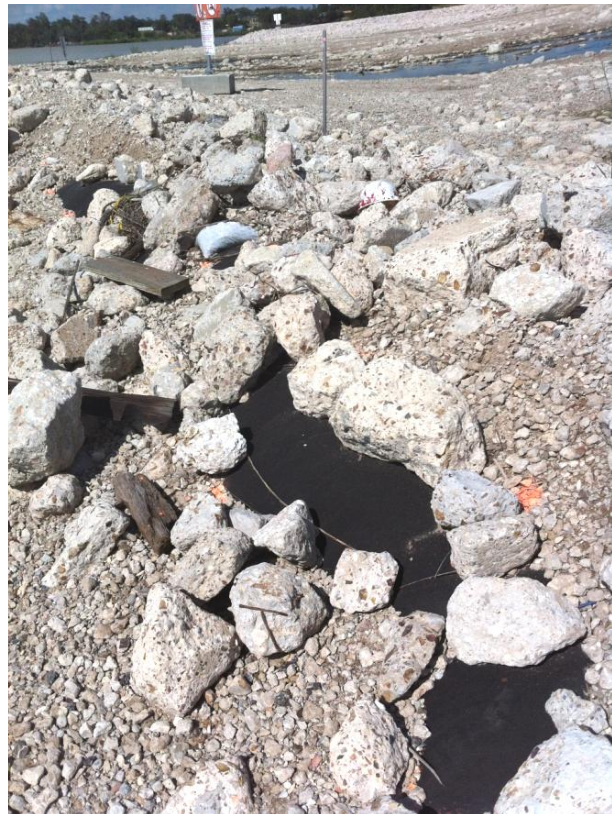

Figure 3. West berm close-up. Figure 4. Exposed geotextiles close-up.

Subsequent to the July 2012 storm event, a reassessment of the design and construction was conducted on behalf of McGinnes Industrial Maintenance Corporation and International Paper Company by Anchor QEA, LLC (April 2013). The reassessment included a wind wave and vessel wake evaluation and a geotechnical berm stability evaluation, providing a complete design evaluation.

This review examined the Time Critical Removal Action Alternatives Analysis (June 2010), Final Removal Action Work Plan (Feb 2011), Revised Final Removal Action Completion Report (May 2012), TCRA Cap Repair Plan (July 2012), Time Critical Removal Action Report on Reassessment of Design and Construction (April 2013), and miscellaneous construction submittals and weekly reports.

2 Design

The design and construction of the West Berm are not well-described in the design and construction reports. The documents describe five possible cap configurations for the site; however, details of the design focus only on Cap A. The area under review consists of Cap B/C using recycled concrete as described in the Final Removal Action Work Plan (Feb 2011), instead of rock as proposed in Alternative 3 of Time Critical Removal Action Alternatives Analysis (June 2010).

Stone Sizing

Velocity and flow depth are the two basic factors used in design of riprap protection to provide hydraulic stability. The method of determining the stone size in EPA 905-896-004 uses depth-averaged local velocity. Stone size computations should be conducted for flow conditions that produce the maximum velocities at the riprap boundary. However, this approach may not provide the most critical condition when wave runup and overtopping occurs. Under wave runup and overtopping, significant vertical velocities and turbulence are generated at small scales. These velocities in the immediate vicinity, within 1 to 2 meters, of the west berm generate much greater shear stresses than in a uniform flow field.

<u>Hydrodynamics</u>

Anchor QEA modeled the hydrodynamics of high-flow events using the EFDC model in a two-dimensional, vertically-averaged mode. The geometry and bathymetry were represented in the model using variable rectangular cell sizes. The grid cell resolution is 15 x 15 meters (m) in the vicinity of the waste pits and gradually increases to 30 x 30 m farther from the study area. This resolution was found adequate for the general objectives of the modeling study, providing a balance between adequately simulating hydrodynamic processes and conducting long-term, multiyear simulations in the future, within a practical processing time for the model. However, the two-dimensional mode and resolution may not be adequate in the immediate vicinity of the berm to estimate the maximum shear stress along the length of the berm. The steepest section of the berm cross-section is one to two meters in length and the crown of the berm is only 2.5 meters wide; which cannot be well represented with a 15 x 15 m grid cell resolution. Similarly, the impacts of estimated waves during the design events should be included in the analysis to compute the maximum stable particle size. Wave induced velocities on slopes may be about 25% greater than simple advective velocities and shear stresses may be 60% greater, requiring a 75% greater stone size. Waves were considered in the Reassessment of Design and Construction (April 2013).

<u>Stable Armor Size</u>

Anchor QEA computed the stable armor size using the riprap design equation from the USACE Engineer Manual EM 11 10-2-1 601 entitled "Hydraulic Design of Flood Control Channels" (USACE 1994) as modified by Maynord (EPA 1998).

$$D_{50} = S_f C_s C_v C_T C_G d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{\frac{1}{2}} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5}$$

Where

D_{50} = median particle size in feet

S_f = safety factor

C_s = stability coefficient for incipient failure

C_V = velocity distribution coefficient

C_T = blanket thickness coefficient

C_G = gradation coefficient = $(D_{85}/D_{15})^{1/3}$

D_{85}/D_{15} = gradation uniformity coefficient

d = water depth in feet (from the hydrodynamic model)

γ_s = unit weight of stone

γ_w = unit weight of water

V = local depth averaged velocity, use velocity at 20 percent upslope from toe for side slope riprap; Anchor QEA applied maximum depth-averaged velocity in feet per second (from the hydrodynamic model)

K_1 = side slope correction factor

g = acceleration due to gravity

The Hydrodynamic Design, Appendix G (Anchor QEA November 2010) did not provide the values for the parameters in this equation that were used in their design analysis.

The model velocities from a 15 x 15 m grid may not be sufficient to define the local depth averaged velocity at 20 percent upslope from toe for side slope riprap, consider effects of waves and overtopping, or model the small scale impacts of the steep slope of the berm (about 1 meter rise over 1 meter run). These shortcomings would tend to underestimate the local shear stresses on the steep face of the berm and therefore underestimate the stable armor size. To accommodate uncertainties in the armor sizing, the design equation uses a safety factor (typically, a minimum of 1.1); however, a larger safety factor (1.3 to 1.5) would be appropriate considering the processes not included in this design equation for flood control channels.

Armor Material Uniformity

The gradation uniformity coefficient of the armor material is another important factor in the armor sizing as well as filtering and material retention. Armor material may be either uniform or graded. Graded material was used to armor the San Jacinto west berm. Graded armor material should have a uniformity coefficient of no more than 6.7. Less uniform material requires a larger D_{50} for the material. The typical range in uniformity coefficient is 1.7 to 5.2 and preferable range is 1.8 to 3.5. The uniformity coefficient of the armor material used at San Jacinto was not provided; the material specifications were only for D_{100} and D_{50} with less 4% pass through a 200 sieve. Cap B/C specifications call for crushed natural rock with a D_{100} of <12 inches and a D_{50} of <6 inches, but the placed material is recycled concrete that appears to have had an excessive quantity of particles with sizes in the range of gravels and sands based on the pictures in Figures 1 through 4. The recycled concrete does not meet the desired uniformity coefficient without processing it through a coarse bar screen or grizzly screen to remove the fines. The sieve analysis on the B/C material presented in Appendix L of the Revised Final Removal Action Completion Report (May 2012) were inadequate to define the uniformity coefficient or the coefficient of curvature for the material. The D_{30} and D_{10} of the material are not individually bracketed; both are between 0.0035 inches and 6 inches, a range of more than 3 orders of magnitude. At a minimum, data should have been collected also at 9 inches, 8, 7, 5, 4, 3, 2, 1 and 0.5 inches as it was collected for Armor Cap C composed of natural rock.

Side Slope

The side slope also plays a role in armor sizing; steeper slopes require a larger D_{50}. The slopes vary across the cross section of the berm. The outside of the berm was not graded to a uniform slope prior to armoring. The Final Removal Action Work Plan (Feb 2011) indicated that the western and central berm will be slightly regraded in order to create a more stable surface for placing cover. The limited regrading will entail flattening steep slopes along the central and western berms, but the grading decisions will occur during construction after site clearing and grubbing is completed. Figures 2, 3 and 4 show slope sections that appear to be as steep as 1V:1H, while the exterior slope was designed to be no more than 1V:3H. It is unclear what slope was used in the design analysis for sizing, but the steepest slope should have been used. Repair of the west berm should establish a surface slope no greater than 1V:3H to limit displacement during the combined action of waves and overtopping flow.

Stone Size

The adequacy of the stone size cannot be determined without additional information on the armor stone characteristics, velocities, bottom shear stress, depths, and slopes. However, based on the Reassessment of Design and Construction (April 2013) as well as the Final Removal Action Work Plan (Feb 2011). The recycled concrete B/C does not appear to be adequate at slopes greater than 1V:3H due to an excessive quantity of particles smaller than 2 inches. Cap C armor material appears to be adequate for repairs if placed to a final surface slope no greater than 1V:3H.

Filter

Armor caps can be designed in three manners: 1) traditional with a base layer, filter layer and armor layer, 2) a graded armor layer (blended filter-sized stones and armor size stones) over the base layer, and 3) a base layer, geotextiles filter and armor layer. The first option is the common method for shallow marine construction; the second option is becoming a common option for deep water environments with shallow slopes; and the third option is commonly applied on shorelines with moderate to steep slopes. At San Jacinto the armor cap was designed with options 2 and 3 or a combination of options 2 and 3. Cap Configuration A consisted of geotextile placed on the base layer for constructability and then capped with blended armor and filter stones. The filter material also provided a bedding to protect the geotextiles from puncture by armor stone during construction. Cap Configurations B, C, D and E in the Final Removal Action Work Plan, Appendix A: TCRA Technical Specifications (September 2010) do not call for the use of armor stone blended with filter stone. Nevertheless, Figures 1 through 4 show a large quantity of gravels and sand in the Cap B/C, resembling a blended filter.

The use of blended stones in locations of steep to moderate slopes (greater than 1V:3H) at velocities greater than 1.3 m/s is not recommended. The filter size stones will rearrange themselves and move down the slope, vacating areas at the top of the slope until a stable slope is achieved under the given shear stress. As the filter stones vacate areas, the voids created will make the armor stones unstable as well and cause them to relocate down the slope as well. Velocities were predicted to be as large as 1.98 m/s in the southwestern corner of the berm. Therefore, the armor stone should have been graded (screened) to limit the quantity of filter size stone and increase the uniformity of the armor stone. Repair of the west berm with Armor Cap C material is appropriate.

Stone Gradation

The armor stone specification is not well specified. The TCRA Technical Specifications, Appendix A (Anchor QEA November 2010) and USA Submittal 10 (Anchor QEA Feb 2011) cite only that 100% of the stones passes 12 inches with no more than 50% passing 6 inches and no more than 4% passing the #200 sieve. The armor stone should have had a specification of no more than 10% passing 2 inches to improve the uniformity and stability. The pictures in Figures 1 through 4 show an excessive quantity of gravel and sand size particles.

Slope

The slope of an armored bank should not generally exceed 1V:2H and in an area with overtopping and waves breaking should not exceed 1V:3H. Appropriately, the slope of the west berm was designed to be no more than approximately 1V:3H; however, Figures 2, 3 and 4 show slope sections that appear to be as steep as 1V:1H. The face of the berm shown in these pictures should have been filled with bedding material to ensure that all slopes were no greater than 1V:3H where high velocities, waves and overtopping may occur.

Thickness

The minimum thickness of an armor layer should be the larger of D_{100} and $1.5D_{50}$. Typical designs use a thickness of the larger of $1.5D_{100}$ or $2D_{50}$ for rounded stone. The armor cap design used at San Jacinto specified a minimum of $2D_{50}$, which is appropriate.

3 Construction

This review of the construction is quite limited and is based on the construction reports, submittals and inspection reports.

Slope

The construction specifications did not include grading the water side of the west berm or adding fill to create a uniform slope. The slope should have been brought to the desired grade prior to placement of a geomembrane or geotextiles.

Armor Cap Gradation

The Remedial Action Work Plan specified that the contractor "Verify Quality of Import Material. Import material must meet specified physical and chemical properties, as detailed in the Specifications, prior to the use of an imported material." A contractor submittal at the start of construction demonstrated that the material met the specifications; however, the gradation was not adequate to define the uniformity or the gradation curvature. No additional testing was presented to demonstrate and verify the consistency and uniformity throughout the project. A procedure should have been in place to verify the uniformity coefficient of the armor cap material. Ideally, a grizzly screen would have been used at the site to remove stone less than two inches from the Armor Cap B/C material. The fines could have been used at the site for base and filter material.

Thickness

The Remedial Action Work Plan specified the "Contractor will perform quality control topographic and hydrographic surveys during Armored Cap placement, as described in the Specifications. The control for this system must meet 0.25-feet vertical accuracy for in-water placement. Accuracy for topographic surveys completed for upland work must been 0.01-foot accuracy. These surveys will be performed at a minimum of every 2 working days to establish actual extent and thickness of Armored Cap placement. Hydrographic surveys will be performed using a single-beam, dual-frequency or multi-beam, single-frequency echosounder system, or with a rod and staff if the water depth is too shallow for boat access. If a single-beam system is used, the trackline spacing will be no greater than 25 feet to minimize interpolation error. This specification is sufficient to ensure adequate thickness of the placed cap.

4 Repair

The TCRA Cap Repair Plan (July 2012) identified maintenance procedures for the outer slope of the western berm. Additional material was placed to create a slope of 2H:1V or flatter so that at least 12 inches of armor rock is covering the geotextiles as required by the Removal Action Work Plan (Feb 2011). The material used for maintenance activities was from the Armor Cap C stockpile.

Since the existing material in the maintenance area is recycled concrete characteristic of blended filter/armor and contains a considerable quantity of particles that are smaller than 2 inches, sufficient material should be added to flatten the slope to 1V:3H or flatter to retain the gravels in the mixture. Use of Armor Cap C material is appropriate for maintenance and should be sufficiently stable when placed at a slope to 1V:3H or flatter.

5 Conclusions

Review of the design and construction of the armor capping of the west berm of the San Jacinto Waste Pits Superfund Site indicates several issues of concern.

1. Parameterization of the stone size equation. The inputs to the equation were not provided. The design velocity from the hydrodynamic model may not account adequately for the slope changes due to limitations in spatial resolution. The factor of safety may not have adequate for the uncertainties in construction, slopes, material gradation, waves, non-uniform flow, flow constrictions and overtopping.
2. Slope. The slope of the face of the berm just below the crown was much steeper than the design slope and was not modified prior to capping. For the non-uniform recycled concrete used for Armor Cap B/C, the design slope should have been 1V:3H or flatter to prevent excessive displacement and loss of gravel and sand sized particles.
3. Armor cap material gradation. The uniformity of the armor cap material was not specified. The material specifications allowed too much gravel and sand sized particles to be used, which could be eroded from the cap because they did not meet internal stability and retention criteria. Greater uniformity of the armor cap is preferable in the high energy regimes of the cap, particularly the southwestern corner of the berm.
4. Repair should ensure that the final surface throughout the repair area and adjacent areas has a slope of 1V:3H or flatter.

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